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DRY AND WET ARC TRACK PROPOGATION RESISTANCE TESTING

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Presentation Overview:

- History of NAVAIR interest and involvement in Insulation Arc Track Propagation Resistance testing
- Recent developments in NAVAIR's involvement with Insulation Arc Track Propagation Resistance testing
- Parameters common to both Wet and Dry Arc Tests of MIL-STD-2223
- Wet Arc Track Propagation Resistance Test MIL-STD-2223 method 3006
- Dry Arc Track Propagation Resistance Test MIL-STD-2223 method 3007
- Video of NAWC AD Indianapolis Wet and Dry Arc Resistance Test Equipment
- Tensolite Co. slow motion video of arc initiation in the Dry Arc Test
- NAWC AD Indianapolis Wet and Dry Arc Track test capabilities

Early History of NAVAIR's Involvement with Wire Arc Track Testing

- Informal testing of energized wire bundles with small arms by Navy personnel
- Ballistics testing of Polyimide and XLETFE insulated wires at NAWC AD Pax River, MD (NATC)
- Testing of various wire insulations at the Naval Research Labs (NRL) Washington, DC
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- Major factor in NAVAIR's decision to no longer use MIL-W-81381 Polyimide insulated wires and to replace MIL-W-81381 wire in installed aircraft with MIL-W-22759 crosslinked ETFE insulated wires during aircraft maintenance

Recent Events in NAVAIR's Involvement with Wire Arc Track Testing

• Monitoring industry and government activity with Insulation Arc Track Propagation Resistance testing

• Industry development of hybrid insulation systems with Polyimide (arc propagating insulation) in combination with fluoro-polymer insulations (arc propagation resistant insulation) made development of laboratory arc track propagation resistance tests critical to evaluate the new insulation systems

• Government-industry task group chaired by NAVAIR formed to write MIL-W-22759/80-92 specification sheets for PTFE/Polyimide hybrid insulation wires and develop standardized and repeatable Wet and Dry Arc Propagation Resistance Tests for MIL-STD-2223 capable of reference in the new wire specification sheets

Parameters common to Wet and Dry Arc tests of MIL-STD-2223

Bundle with 7 wires, the top 5 wires energized using 20 KVA , 400 Hz, 208 Volt, 3 phase power and lower two not energized

Arc is initiated between the top two wires of bundle (phase A1 & B1) and allowed to propagate until a thermal CB trips, continuity is lost in both of these wires, or the test runs to a defined endpoint with no arc event occurring

If breakers on the damaged wires trip, breakers are reset one time to restrike the arc

Pass/fail criteria is determined by measuring the length of wire damage due to arc propagation and the ability of the 5 middle and bottom wires in the bundle that are <u>not</u> intentionally damaged to pass a post test dielectric withstanding voltage test

3 wire bundles are tested with 0, 0.5, 1, 1.5, and 2 ohms resistance in the circuit. This provides 15 wire bundles to be tested. The dielectric withstanding pass/fail criteria counts the number of the 75 wires (15 bundles x 5 wires) that are not intentionally damaged that pass the dielectric test. MIL-W-22759/80-/92 requires at least 70 wires to pass for the normal weight wire and at least 67 to pass for the light weight wire

Wet Arc Track Test Method 3006 of MIL-STD-2223

Mil-STD-2223 test is based on similar tests required by Boeing specification BMS 13-60, and ASTM D3032 section 27, and BSI test methods

This test methodology is now widely accepted in US and Europe

Arc initiated by cutting a .75- 1.0 mm window 360 degrees around the two top wires of the 7 wire bundle (A1 and B1) and arranging the wires with the stripped windows 6.25 mm apart then dripping 3 % NaCl solution on the energized bundle at 8-10 drops/minute

A nonarc event test is declared and the test stopped if the two top conductors erode away (no continuity) and no breakers trip after 8 hours.

Dry Arc Track Test Method 3007 of MIL-STD-2223:

This test methodology is not as standardized as the Wet Arc Track test yet

- All dry arc methods use an electrical short being induced across energized wires of a bundle initiated by one of the following means:
- Wires shorted by ballistic projectile
- Wire strand used to short between exposed conductors
- Exposed ends of the wire bundle shorted using graphite powder or copper dust
- Reciprocating abrader blade "sawing" through insulation used to induce a short

Many different methods have been used until recently

The reciprocating blade method is rapidly becoming the standard test method:
Military - MIL-STD-2223 method 3007
McDonnell Douglas St. Louis specifications 5M2071 through 5M2074
Boeing Commercial Aircraft Specification BMS 13-60 and BSS 7324 test standard
ASTM D3032 section 29

Dry Arc Track Test Method 3007 of MIL-STD-2223:

Arc is initiated by a reciprocating blade connected to the neutral of the 3 phase power "sawing through" the A1 and B1 phase wires on the top of the 7 wire bundle

A nonarc event is declared and the test stopped if the blade contacts a mechanical stop set to stop the blade before it can damage wires other than the top 2 wires used to initiate the arc

There are many more variable to be controlled compared to the wet test due to the mechanical contact between the abrader blade and the wire bundle

NAWC AD Indianapolis Test Capabilities:

NAWC AD Indianapolis has Wet and Dry Arc Arc Track Propagation Resistance test capabilities at this time

NAWC AD Indianapolis is the designated qualification test lab for wet and dry track propagation resistance testing for the MIL-W-22759/80-/92 PTFE/Polyimide hybrid insulation wires

NAWC AD Indianapolis is NAVAIR's lab for arc track evaluation of new wire insulation sytems and hopes to work with other military, government, and commercial activities to perform arc track evaluations of new insulation systems and to advance the state of the art in insulation arc track testing

NAWC AD Indianapolis is promoting the Mil-STD-2223 test methods to other activities for arc track testing so test results taken at different activities can be correlated and compared

METHOD 3006

WET ARC-PROPAGATION RESISTANCE

1. PURPOSE. The wet arc-propagation resistance test for wire insulation provides an assessment of the ability of an insulation to prevent damage in an electrical environment. In service, electrical arcs may originate from a variety of factors including insulation deterioration, faulty installation, and chafing, and may be further induced by water or other fluids which create conductive paths. It has been documented that results of an arc-propagation test may vary slightly due to the method of arc initiation; therefore a standard test method must be selected to evaluate the general arc-propagation resistance characteristics of an insulation. This test method initiates an arc by dripping salt water over pre-damaged wires which creates a conductive path between the wires. The arc propagation resistance is defined by the length of arc-propagation damage along the pre-damaged wires and by the extent of damage to all adjacent wires which are initially undamaged. The test also evaluates the ability of the insulation to prevent further arc-propagation when the electrical arc is re-energized. The power supply, test current, circuit resistances, and other variables are optimized for testing 20 gauge wires. The use of other wire sizes may require modifications to the test variables.

2. TEST EQUIPMENT

a. A transparent screen to protect laboratory personnel from molten metals, UV radiation, and other debris that may be ejected from the test specimen.

b. A variable speed, peristaltic pump or suitable other device and a hypodermic needle or burette. The apparatus should be able to deliver the electrolyte solution at a rate of 100 ± 10 mg (0.0035 ± 0.00035 ounces) per minute (8 to 10 drops of 3 percent sodium chloride solution) to the test specimen. An alternative means of delivery is acceptable.

c. A mechanical device for supporting the test bundle in free air in a horizontal position.

d. An electrolyte solution made by dissolving 3 ± 0.5 percent by weight of sodium chloride (NaCl) in distilled water.

e. A three phase wye connector power supply, grounded at wye, derived from a rotary machine or solid state power source of not less than 20 KVA rating, delivering 208 volts line-to-line at 400 Hz.

f. MS3320-7.5 (7.5 Amp) and MS25244-50 (50 Amp) protective circuit breakers.

g. Variable load and fixed load resistors.

h. MIL-T-43435 (Type V) lacing tape.

3. TEST SAMPLES. A test sample shall consist of 15 bundles of wire. Each bundle is composed of seven wires approximately 20.3 - 40.6 cm (8 - 16 inches) in length. A minimum of 21.3 meters (70 feet) is required. It is recommended that 20 gauge wire be use for the test.

4. TEST PROCEDURE

4.1 Preparation of bundles. Conduct a 2500 volt Wet Dielectric test on 100 percent of the wire in accordance with the Wet Dielectric test procedure described in MIL-STD-2223 method 3005 before the arc-propagation resistance test is performed. Discard any failed sections of wire. Cut seven wire segments 20.3 - 40.6 cm (8 - 16 inches) in length for each of the 15 bundles. Clean the cut wires using a cloth saturated with isopropyl alcohol. Strip both ends of five of the seven wire segments. Use these stripped ends for making electrical connections. These five wire segments will be called "Active Wires". The two unstripped wire segments will be called "Passive Wires". Using a sharp blade, cut a square groove completely around (360 degrees) the insulation of two of the active wires at their midpoints to expose the conductor. The width of the exposed conductor should be between 0.5 mm and 1.0 mm (0.0197 and 0.03941 inch). Form the bundle by laying the seven wire segments straight and geometrically parallel. Assemble the wires to form the six-around-one configuration shown in Figure 1. The two pre-damaged wires should be placed in the A1 and B1 positions and care should be taken to ensure that there is a longitudinal distance of 6.0 mm to 6.5 mm (0.2362 to 0.2560 inch) as measured between the stripped window of the two exposed conductors. The two passive wires correspond to the D1 and D2 components shown in Figure 1. Use MIL-T-43435 lacing tapes to hold the test bundle together. Clean the assembled bundle using a cloth saturated with isopropyl alcohol prior to installation in the fixture.

4.2 Electrical connection. Connect the test bundle to the power supply and circuit resistance using the schematic circuit shown in Figure 2. Connect one end of each active wire to the appropriate phase of the power supply as shown in Table I. Use an MS3320-7.5 (7.5 Amp) circuit breaker and a circuit resistance in series with each of the active wires. Use the circuit resistance values shown in Table II. Connect the other end of the five active wires under test to variable resistive loads. Adjust the resistance to limit the current flowing through each wire to 1 ± 0.2 Ampere. Protect the test circuits with MS25244-50 (50 Amp) circuit breakers connected on the supply side of the test set up.

TABLE I. Electrical connection.

Wire Identification	Power Supply	Layer
A1	Phase A	Top
B1	Phase B	Top
C1	Phase C	Middle
A2	Phase A	Middle
B2	Phase B	Middle
D1	None	Lowest
D2	None	Lowest

TABLE II. Circuit resistance.

Test Number	Circuit Resistance (ohm)
1	0.0
2	0.5
3	1.0
4	1.5
5	2.0

4.3 Initiation of test. Test three bundles for each of the five circuit resistances. Using the mechanical supports, mount the test bundle in a draft-free location so that the wires with the exposed conductors are upper most. Adjust the flow of the electrolyte to 8-10 drops per minute. Position the hypodermic needle to drop the electrolyte into the groove between the wires with the exposed conductor. Position the tip of the needle so that the vertical distance of the tip is 150 mm (5.91 inch) above the specimen. Position the protective screen to shield the operator from ejecting objects or UV radiation. Close all circuit breakers. Allow the electrolyte to flow. Apply three phase 400 Hz power.

5. RESULTS. Use one of the following conditions to conduct and complete the test.

5.1 If circuit breakers in any of the phases A2, B2, or C1 trips at any time during the test, wait 3 minutes and disconnect power. Conduct a 1000 volt Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet Dielectric procedure of MIL-STD-2223 method 3005. Record the number of wires which fail. Measure and record the total length of physical damage to each wire (including phase A1 and B1 wires) in inches.

5.2 If either phase A1 or phase B1 circuit breaker trips at any time during the test, disconnect the power and identify the phase of the tripped circuit breaker. Wait 3 minutes. Reset the circuit breaker, apply power and continue the test. Continue the test for eight hours or until either phase A1 or phase B1 circuit breaker has tripped twice. CAUTION: DO NOT RESET A CIRCUIT BREAKER THAT TRIPS TWICE. Conduct a 1000 volt, Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet Dielectric test of MIL-STD-2223 method 3005. Record the number of wires which fail. Measure and record the total length of physical damage to each wire (including phase A1 and B1 wires) in inches.

5.3 If the conductor(s) of phases A1 and B1 wires erode without tripping phase A1 or phase B1 circuit breakers (as may be indicated by an open circuit indicator), continue the test for a total of 8 hours or until the test endpoints of 5.1 or 5.2 occur. Conduct a 1000 volt Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet dielectric procedure of MIL-STD-2223 method 3005. Record the number of wires which fail. Measure and record the total length of physical damage to each wire (including phase A1 and B1 wires) in inches.

5.4 Circuit breakers should be periodically tested to assure they still meet the overload trip requirements of the applicable military specification (MS) sheet. Circuit breakers outside their overload trip limits should be replaced.

6. INFORMATION REQUIRED IN THE INDIVIDUAL SPECIFICATION. Specifications shall list minimum number of wires which must pass the dielectric test after the bundle has been energized, and also the maximum allowable length of physical damage to the individual wires in the bundle.

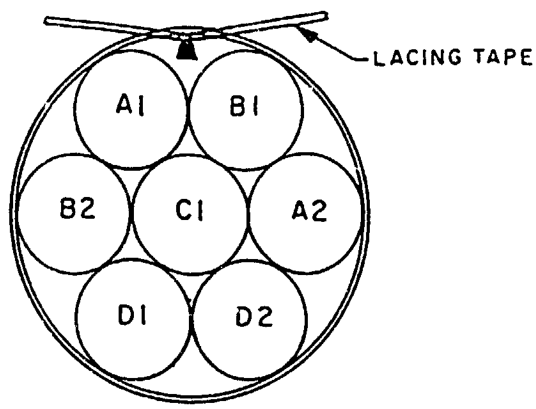

FIGURE 1. Bundle Configuration.

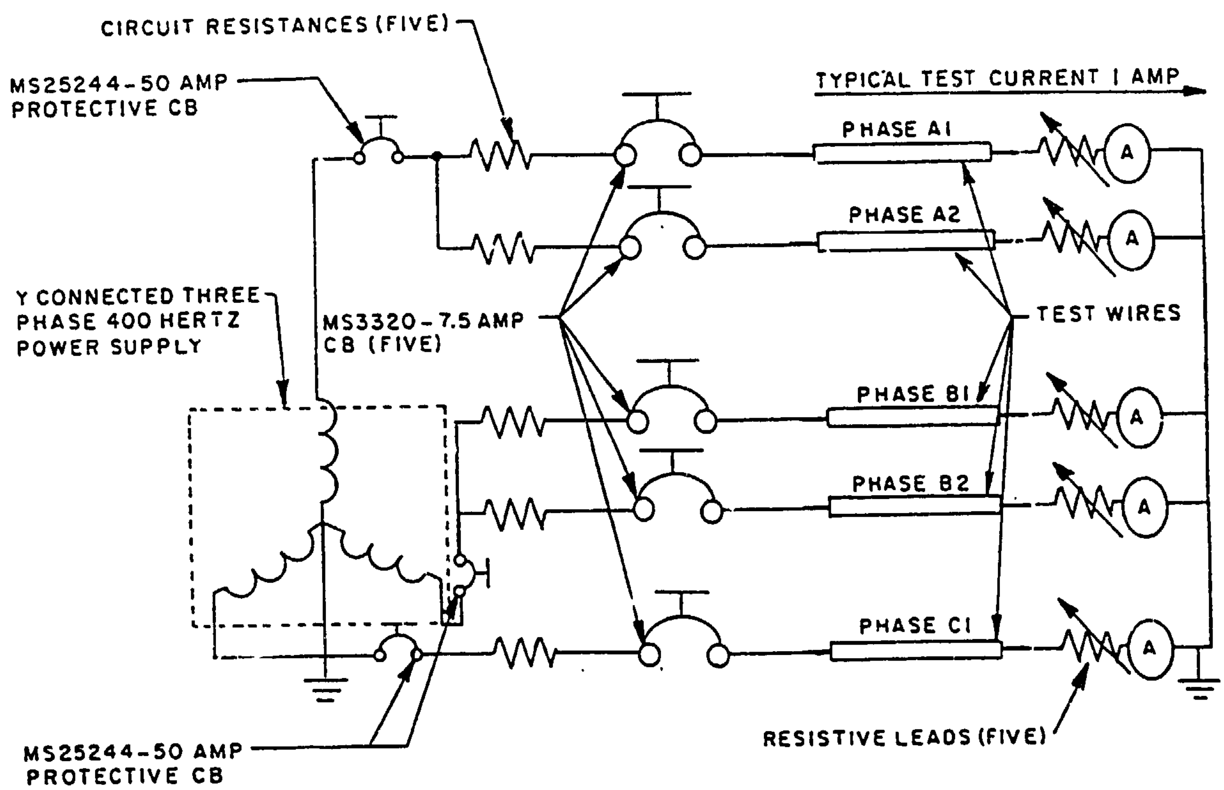

FIGURE 2. Electrical Connection

METHOD 3007

DRY ARC-PROPAGATION RESISTANCE

1. PURPOSE. The dry arc-propagation resistance test for wire insulation provides an assessment of the ability of an insulation to prevent damage in an electrical arc environment. In service, electrical arcs may originate from a variety of factors including insulation deterioration, faulty installation, and chafing. It has been documented that results of an arc-propagation test may vary slightly due to the method of arc initiation. Therefore a standard test method must be selected to evaluate the general arc-propagation resistance characteristics of an insulation. This test method initiates an arc with a vibrating blade. The arc-propagation resistance is defined by the length of arc-propagation damage along the wires in contact with the blade and by the extent of damage to all adjacent wires undamaged by the vibrating blade. The test also evaluates the ability of the insulation to prevent further arc-propagation when the electrical arc is re-energized. The power supply, test current, circuit resistances and other variables are optimized for testing 20 gauge wires. The use of other wire sizes may require modification of other test variables.

2. TEST EQUIPMENT

a. An abrader blade made from 6061-T6 aluminum material. Use a grit size 60 grinding wheel or 60 grit sanding belt to sharpen the blade. A typical abrader blade is shown in Figure 1. Use the blade sharpening fixture shown in fixture shown in Figure 2.

b. A transparent screen to protect laboratory personnel from molten metals, UV radiation, and other debris that may be ejected from the test specimen.

c. An oscillating mechanism to which the abrader blade is connected. The oscillating mechanism shall provide a stroke of 3.81 cm (1.50 inches) at a frequency of 0.5 ± 0.05 cycles per second.

d. A test fixture which includes a test block to hold the wire at right angles to the abrading blade. The block is made from 6061-T6 aluminum.

e. A three phase wye connected power supply, grounded at wye, derived from a rotary machine or solid state power supply of not less than 20 KVA rating, delivering 208 volts line-to-line at 400 Hz.

f. A mechanical stop constructed of stainless steel.

g. MS3320-7.5 (7.5 Amp) and MS25244-50 (50 Amp) protective circuit breakers.

h. Variable load and fixed load resistors.

i. MIL-T-43435 (Type V) lacing tape.

j. MS25281 plastic clamps.

3. TEST SAMPLES. A test sample shall consist of 15 bundles of wire. Each bundle is composed of seven wires and shall be of sufficient length, 35.6 cm (14 inches) minimum, to allow the bundle to be installed in the test fixture. A minimum of 37.3 meters (122.5 feet) of wire is required. It is recommended that 20 gauge wire be used for the test.

4. TEST PROCEDURE

4.1 Preparation of bundles. Conduct a 2500 volt Wet Dielectric test on 100 percent of the wire in accordance with the Wet Dielectric test procedure described in MIL-STD-2223 method 3005 before the arc propagation resistance test is performed. Discard any failed sections of wire. Cut seven wire segments at least 35.6 cm (14 inches) in length for each of the 15 bundles. Clean the cut wires using a cloth saturated with isopropyl alcohol. Strip both ends of five of the seven wire segments. Use these stripped ends for making electrical connections. These five wire segments will be called "Active Wires". The two unstripped wire segments will be called "Passive Wires". Form the bundle by laying the seven segments straight and geometrically parallel. Assemble the wires to form the six-around-one configuration shown in Figure 3. Use MIL-T-43435 lacing tapes to hold the test bundle together. Clean the assembled bundle using a cloth saturated with Isopropyl alcohol prior to installation in the test fixture.

4.2 Bundle installation. A test fixture shall be used to hold the wire bundle in place perpendicular to the abrader blade. Details of a suggested test fixture are shown in Figure 4. Before installation, the wire bundle shall be tied with MIL-T-43435 lacing tape at .635 cm (.25 inch) on each side of where the abrader blade is to be applied; then secured to the test fixture. The wire bundle is clamped with MS25281 plastic clamps at two points on the fixture at a minimum distance of 15.24 cm (6.0 inches). The clamp points are equidistant from the point of application of the abrader. The slide bolt allows the adjusting screw to move the holding plates snugly against the bundle. Ensure that the active wires A1 and B1 are parallel with the top plane of the test fixture, and that the passive wires D1 and D2 are in complete contact with the base of the test fixture. The bundle must not be allowed to move while the abrader blade is cutting wires A1 and B1. The test fixture shall contain an adjustable mechanical stop, which may be set to allow for various penetration depths of the vibrating blade.

4.3 Electrical connection. Connect the test bundle to the power supply and circuit resistance using the schematic circuit shown in Figure 5. Connect one end of each active wire to the appropriate phase of the power supply as shown in Table I. Use an MS3320-7.5 (7.5 Amp) circuit breaker and a circuit resistance in series with each of the active wires. Use the circuit resistance values shown in Table II. Connect the other end of the five active wires under test to variable resistive loads. Adjust the resistance to limit the current flowing through each wire to 1.0 ± 0.2 Ampere. Protect the test circuits with MS25244-50 (50 Amp) circuit breakers connected on the supply side of the test set up. Connect the abrader blade to the neutral of the generator. Connect the generator neutral to ground.

TABLE I. Electrical connection.

Wire Identification	Power Supply	Layer
A1	Phase A	Top
B1	Phase B	Top
C1	Phase C	Middle
A2	Phase A	Middle
B2	Phase B	Middle
D1	None	Lowest
D2	None	Lowest

TABLE II. Circuit resistance.

Test Number	Circuit Resistance (ohm)
1	0.0
2	0.5
3	1.0
4	1.5
5	2.0

4.4 Initiation of test. Test three bundles for each of the five circuit resistances. Install the oscillating mechanism which may use a reciprocating arm. or vertical and horizontal precision linear ball slides (a suggested ball slide apparatus is shown in Figure 6). Adjust the mechanical stop to ensure that the abrader blade penetrates into the A1 and B1 wires a distance of 0.87 times the radius of the seven wire bundles. Close all circuit breakers. Apply a nominal load of 250 grams (0.551 pounds) to the abrader at the point of contact with one wire. Adjust the blade to ensure that the major plane of the blade lies perpendicular to the longitudinal axis of the bundle. Apply the abrader blade on the test bundle. Position the protective screen to shield the operator from ejecting objects and UV radiation. Apply three phase 400 Hz power. Actuate the abrader. Allow the abrader blade movement to continue.

5. RESULTS. Use one of the following conditions to conduct and complete the test.

5.1 If the abrader cuts through A1 and B1 wires without tripping phase A1 or phase B1 circuit breakers, stop the abrader movement. Disconnect the power.

5.2 Conduct the 1000 volt Wet Dielectric test on wires A2, B2, C1, D1 and D2 in accordance with the Wet Dielectric procedure of MIL-STD-2223 method 3005. Record the number of wires which fail. Measure and record the total length of physical damage to each wire (including phase A1 and B1 wires) in inches.

5.3 If a circuit breaker in any of the phases A2, B2 or C1 trips at any time during the test, stop the abrader and disconnect the power. Perform tests as listed in 5.2.

5.4 If either phase A1 or phase B1 circuit breaker trips at any time during the test, stop the abrader. Disconnect the power and determine if the conductor of wires A1 or B1 are open. If both wires are open, conclude the test by performing tests as listed in 5.2. If wire A1 or wire B1 are not open, wait 3-4 minutes, reset the circuit breaker and restart the abrader and then immediately re-apply the power. Continue the test until either phase A1 or phase B1 circuit breaker has tripped a second time, phases A1 and B1 are open, or the blade movement is stopped by the mechanical stop. CAUTION: DO NOT RESET A CIRCUIT BREAKER THAT TRIPS TWICE. Perform the tests as listed in 5.2. Use a new abrader blade edge for each test bundle, if any blade damage is present, or if circuit breakers A1 or B1 trip during the test.

5.5 Circuit breakers should be periodically tested to assure they still meet the overload requirements of the applicable military specification (MS) sheet. Circuit breakers outside their overload trip requirements should be replaced.

6. INFORMATION REQUIRED IN THE INDIVIDUAL SPECIFICATION. Specifications shall list minimum number of wires which must pass the dielectric test after the bundle has been energized, and also the maximum allowable length of physical damage to the individual wires in the bundle.

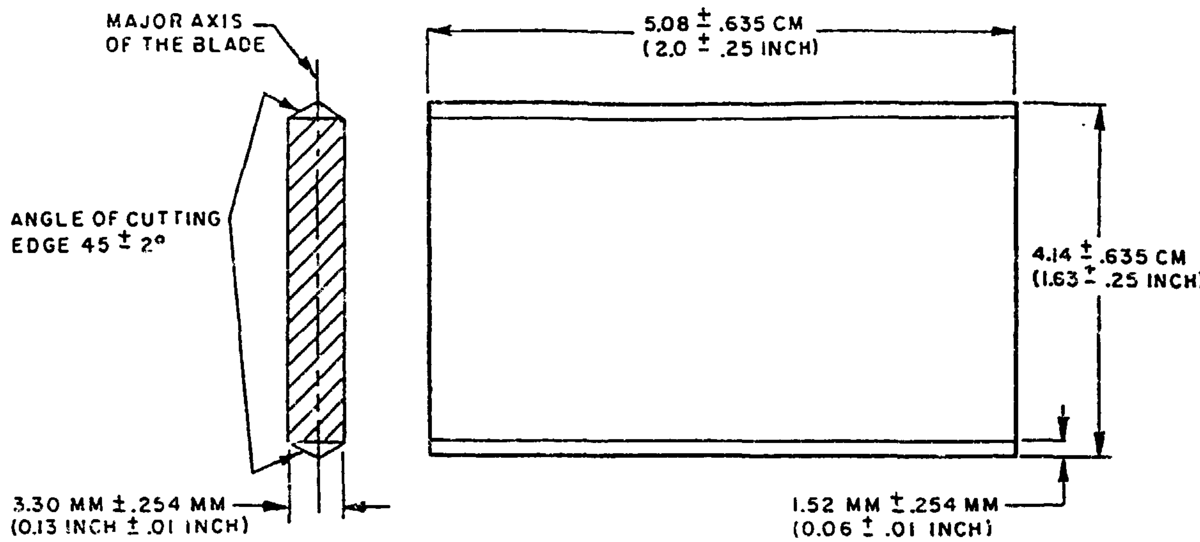

FIGURE 1. Blade.

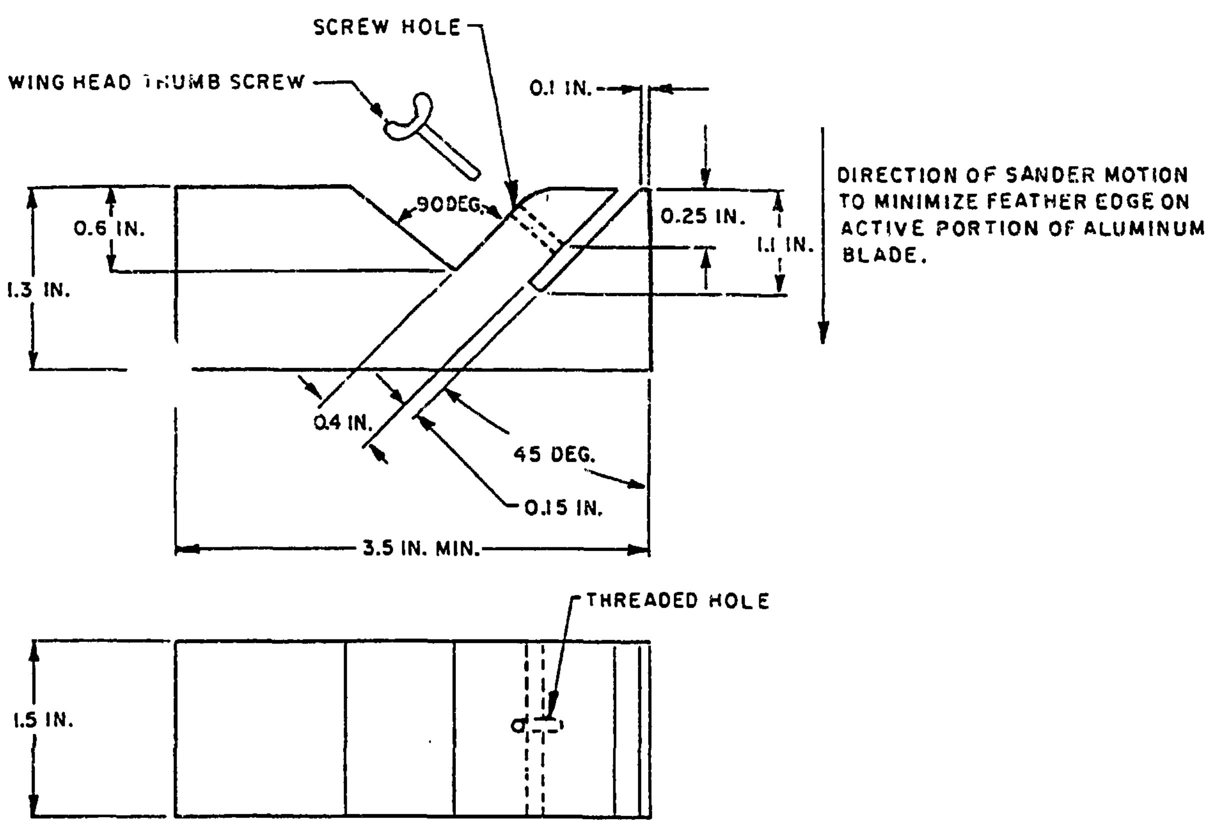

FIGURE 2. Aluminum blade sharpening fixture.

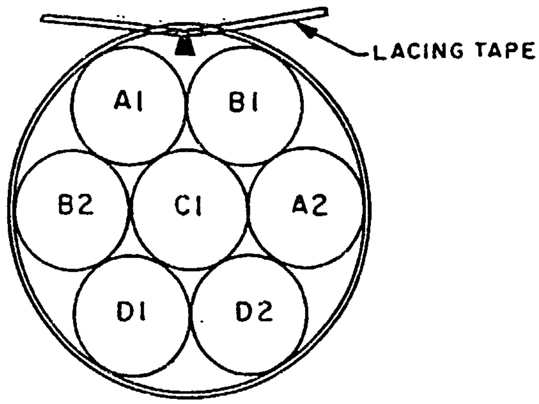

FIGURE 3. Bundle configuration.

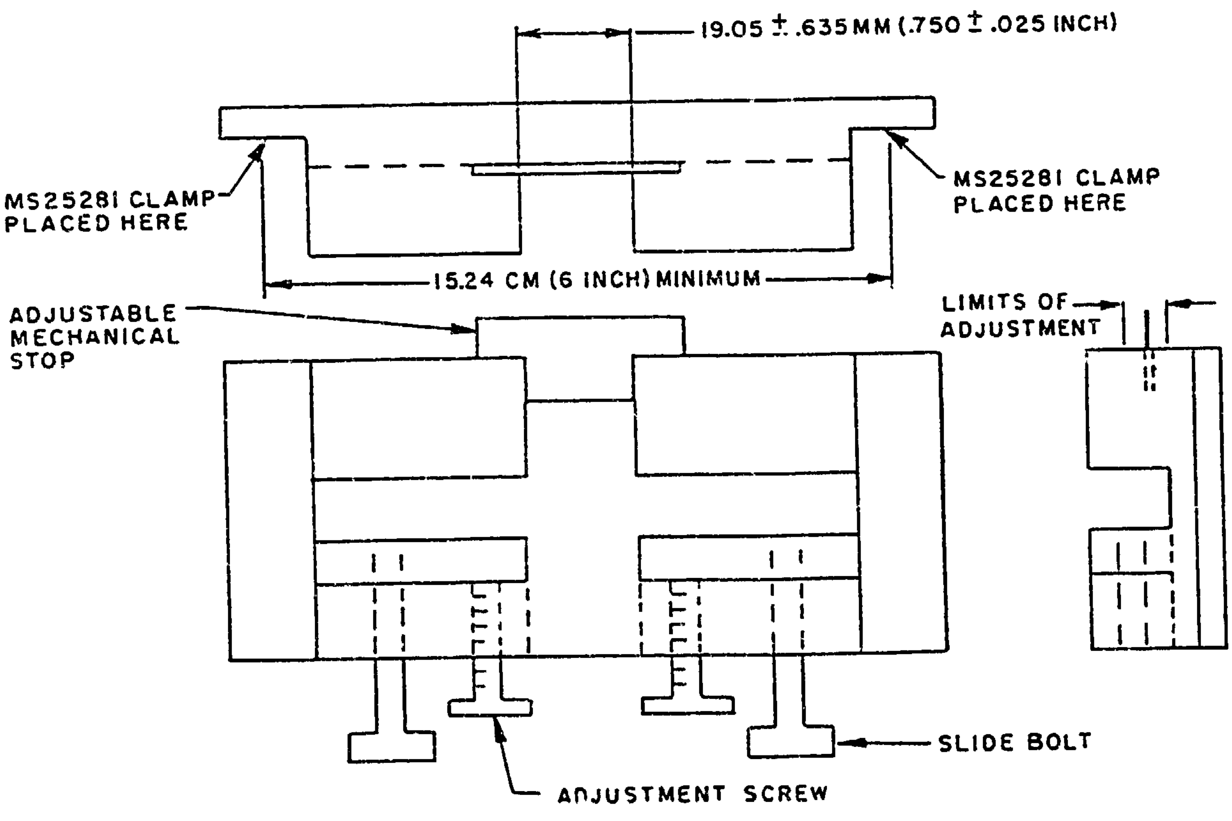

FIGURE 4. Test fixture.

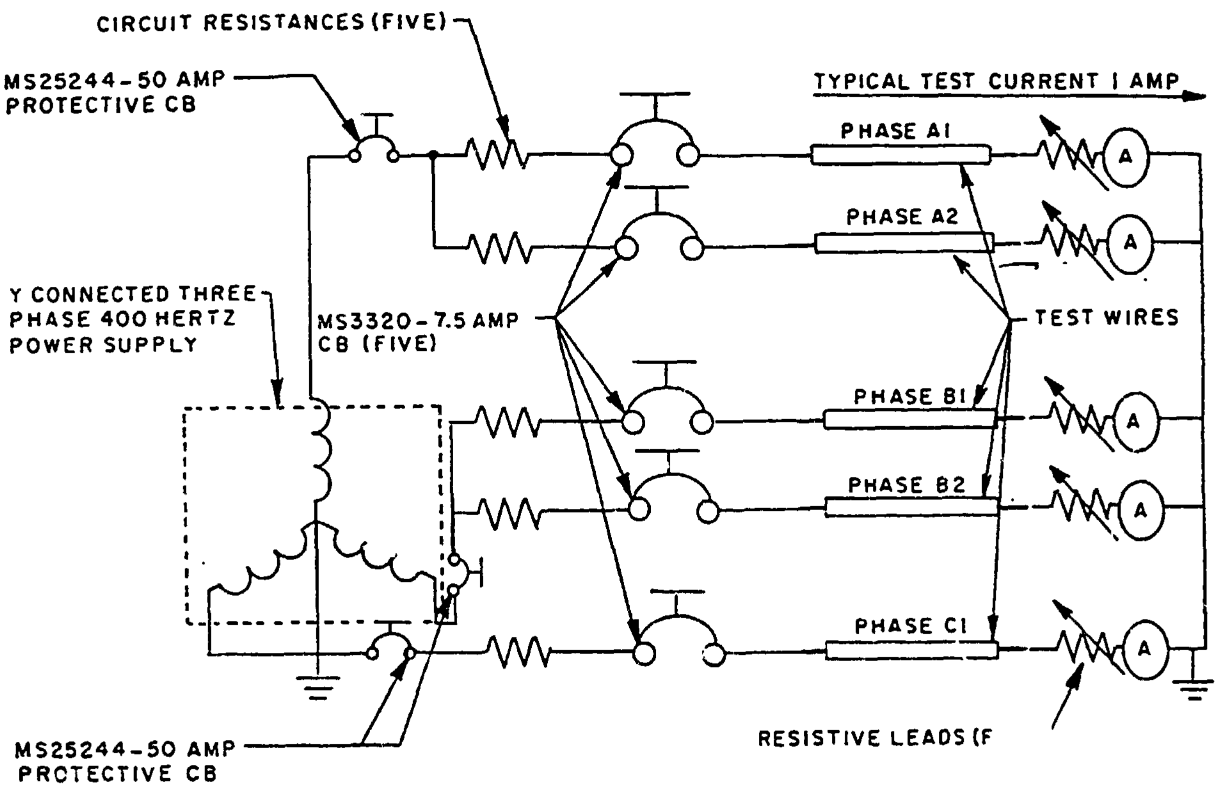

FIGURE 5. Electrical connection.

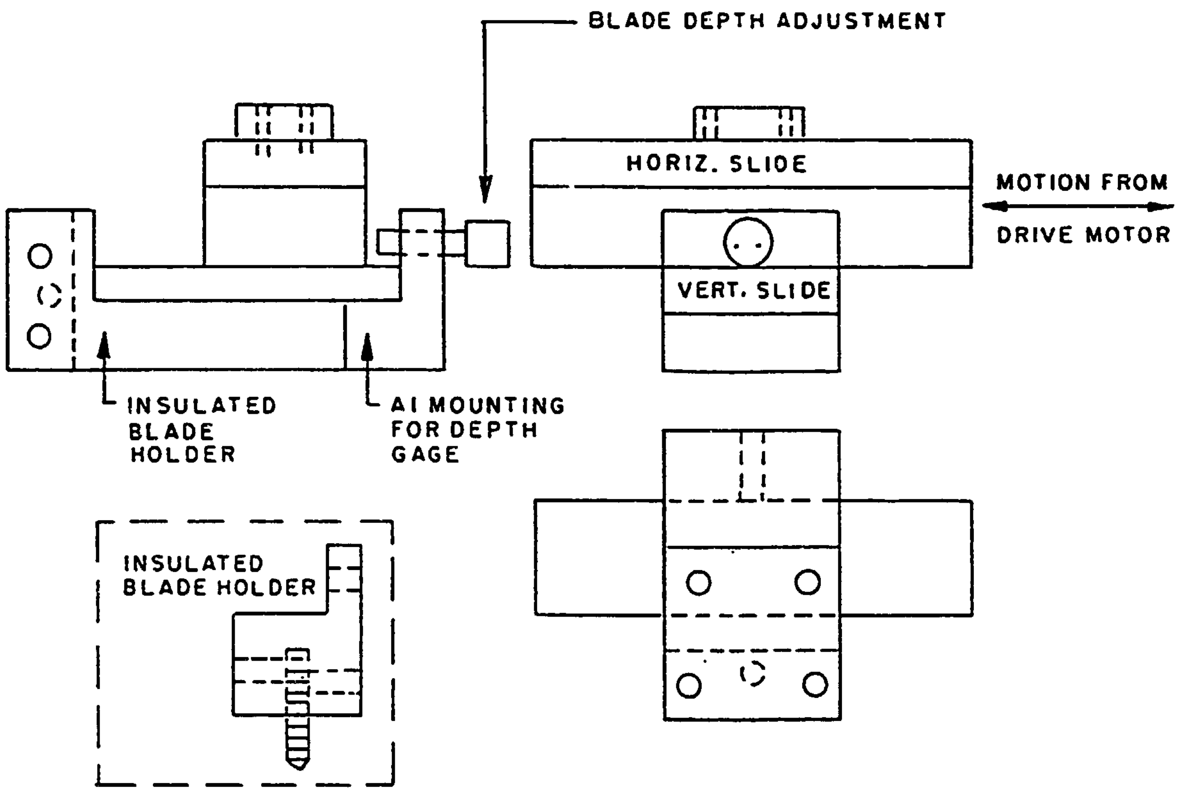

FIGURE 6. Ball slide blade fixture.